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To See Below Location

From **Charles Semah** / WTC 36S / 435-8398 Date 11/ 18/ 93

Re: WTC Fire Alarm System

Attached for your records are the Testing Procedures for Phase I of the referenced project.

Testing for 1 WTC is in progress.

If you have any questions, please call me.

Charles Semah

Att.

To: I. Baron
J. Castaldo (4)
P. Cooper
G. Cummiskey
E. Daly
L. Norcia
A. Reiss
F. Riccardelli

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PA 36
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PORT AUTHORITY OF NY & NJ

FIRE ALARM SYSTEM - FIELD TESTING

PART 1 - GENERAL

1.01 SUMMARY

The following parameters apply to field wiring (performed by the Contractor), connected to the new Pyrotronics MXLV Fire Alarm (F.A.) System, in 1 WTC, 2 WTC, 4 WTC, 5 WTC, Concourse level and all Sub Grade levels. It is important to note that in certain cases, project engineering specifications have exceeded the minimum requirements stated in the MXLV-IOM manual. With this fact in mind, the manual should be consulted as a reference document only.

1.02 REFERENCES

The following is a list of references in this section:

New York City Electrical Code.

New York City Building Code.

Port Authority Fire Alarm Drawings.

Cerberus Pyrotronics Fire Alarm Panel Drawings A & B.

Cerberus Pyrotronics MXLV-IOM Manual.

Port Authority Specifications Sections:

16110 - Raceways.

16120 - Wires, Cables, Splices, Terminations of 600 Volts or Less.

16450 - Grounding.

1.03 SCOPE OF WORK

A. After installation, perform the tests as outlined in Part 3 of this specification, in the presence of the Engineer.

B. A copy of all test reports, together with an outline of the test method used, shall be submitted to the Engineer for review.

C. The Contractor shall certify all field testing and shall submit the test results to the Engineer for approval.

D. Should any of the test results reveal defects, promptly correct such defects and rerun the test until the entire installation is satisfactory to the Engineer.

PART 2 - SYSTEM COMPONENTS

2.01 MATERIALS

A. General

1. Location, type and size of all conduits and wiring are shown on the Contract Drawings.

2. Conduits - Hot-dipped Galvanized Steel Conduit (GSC), with minimum size of 3/4 inch.

3. Power Wiring - 600 Volts, XHHW, 90°C, with minimum size of #12 AWG.

4. Fire Alarm Wiring - Teflon shielded and unshielded 2 conductor cable, #14 AWG, 600V, 200°C, Class "E" Local Law 5, BSA approved.

PART 3 - FIELD TESTS

3.01 NTC WIRING

A. General

1. Network Riser Composition (Network Terminal Cabinet - NTC)

a. RS485 communications network "A" - style 7 (1 pair).

b. RS485 communications network "B" - style 7 (1 pair).

c. Low level audio channel 1 - class A (2 pairs).

d. Low level audio channel 2 - class A (2 pairs).

e. Low level audio telephones - class B (1 pair).

f. Spares (9 pairs).

B. Test Preparations

1. All field wiring prior to testing, must be fully completed, including terminal strip connections, heat shrink insulating tubing, and drain/shield connections, etc.

2. All circuits must be "rung out" to verify proper markings and location.

3. All MXLV/MXLRV hardware connections must first be disconnected to properly test the field wiring, junction points and terminal strip connections.

4. All open connections must be spliced thru, using a temporary "butt-connector" approved by the Engineer.

5. Prior to actual value testing, a final ring out shall be performed to assure that the proper circuits are wired and located as designed.

6. The following connections and test splices must be in place prior to testing:

   a. Style 7, RS485 network "A" - (1) 14/2 shielded originating at the MXLV Head End and terminating at the last MXLRV. Wiring must be removed from PSR-1/NET-7 and spliced thru.

   b. Style 7, RS485 network "B" - same as item 6.a.

   c. Low level audio - channel 1 (2) 14/2 shielded 1 pair used as feed circuit, 2nd pair used as return circuit. Both pairs originate at the MXLV Head End. Feed pairs, including drain wiring, must be removed from each OMM-1/OCC-1 and spliced thru ("spliced thru" indicates removal from a terminal block connection and spliced together. Upon completion of the test the splice will be disassembled, the conductor cut, stripped and returned to it's terminal block). At the last MXLRV the feed pair & return pair must be removed from the OMM-1/OCC-1 & spliced thru to form a continuous loop. Return pair and shield must be strapped thru at each NTC ("Strapped thru " indicates the installation of a jumper without removing the field wiring. All strap wiring must be the same type as the field wire. Upon completion of the test all straps will remain in place).

   d. Low level audio - channel 2 - same as item 6.c.

   e. Low level audio telephones - (1) 14/2 shielded originating from the MXLV Head End and terminating at the last MXLRV. Wiring including shield must be removed from OMM-1/OCC-1 and spliced thru.

   f. Spares - (9) 14/2 shielded originating at the MXLV/NTC Head End and terminating in the last NTC. Each spare circuit pair must be strapped thru in each NTC.

C. EXECUTION

1. General

a. Wiring shall be checked and pre-tested by the Contractor, in accordance with this procedure and the manufacturer's recommendations, to ensure that the system is free of shorts, opens and ground faults.

b. A copy of all pre-test reports (see attached NTC pre-test report), shall be submitted to the Engineer for approval, prior to performance testing.

2. Test performance

a. Visual inspection - Inspect cables for physical damage and proper connection in accordance with the reference drawings.

b. Insulation resistance - Test all wires and cables installed under this contract (and as outlined below), with a 1000-Volt Megohmmeter (megger). Applied potential to be 1000 Volts DC for 1 minute. Minimum insulation resistance values shall be not less than 2 Megohms.

Red Conductor to Black Conductor: _____ MΩ.

Red Conductor to shield: _____ MΩ.

Black Conductor to shield: _____ MΩ.

Red Conductor to ground: _____ MΩ.

Black Conductor to ground: _____ MΩ.

Shield to ground: _____ MΩ.

c. Stray Voltage - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

Red Conductor to Black Conductor: _____ AC Volts.

Red Conductor to Black Conductor: _____ DC Volts.

d. Style 7- RS485 networks A & B - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor:
Network A _____ μF. Network B _____ μF.
Maximum value shall be 0.33 μF.

Red Conductor to shield:
Network A _____ μF. Network B _____ μF.
Maximum value shall be 0.66 μF.

Black Conductor to shield:
Network A _____ μF. Network B _____ μF.
Maximum value shall be 0.66 μF.

2. Resistance

Total of both conductors:
Network A _____ Ω. Network B _____ Ω.
Maximum value shall be 80Ω.

e. Low level audio channels 1 & 2 - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor:
Channel 1 _____ μF. Channel 2 _____ μF.
Maximum value shall be 0.05 μF.

Red Conductor to shield:
Channel 1 _____ μF. Channel 2 _____ μF.
Maximum value shall be 0.1 μF.

Black Conductor to shield:
Channel 1 _____ μF. Channel 2 _____ μF.
Maximum value shall be 0.1 μF.

2. Resistance

Total of (4) conductors:
Channel 1 _____ Ω. Channel 2 _____ Ω.
Maximum combined channels 1 & 2 value shall be 30Ω.

f. Low level audio telephone - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor: _____ μF.

Maximum value shall be 0.05 μF.

Red Conductor to shield: _____ μF.
Maximum value shall be 0.1 μF.

Black Conductor to shield: _____ μF.
Maximum value shall be 0.1 μF.

2. Resistance
Total of both conductors: _____ Ω.
Maximum value shall be 20Ω.

g. Spare wiring - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor: _____ μF.
Maximum value shall be 0.05 μF.

Red Conductor to shield: _____ μF.
Maximum value shall be 0.1 μF.

Black Conductor to shield: _____ μF.
Maximum value shall be 0.1 μF.

2. Resistance
Total of both conductors: _____ Ω.
Maximum value shall be 20Ω.

h. A copy of all test results reports (see attached NTC test results report), shall be submitted to the Engineer for approval.

3.02 TSC WIRING

A. General

1. Terminal Strip Cabinet (TSC) Composition (for number of pairs see TSC drawings):

a. Analog loop drivers (ALD) - class B.

b. Strobe circuits (ZC1) - class B.

c. Telephone circuits (ZCT) - class B.

d. 70V speaker circuits (ZC2) - class B.

e. Interface Cabinet (IC)/ALD circuits - class B.

B. Test Preparations

1. All field wiring, prior to testing, must be fully completed, including terminal strip connections, heat shrink insulating tubing, drain/shield connections, etc.

2. All circuits must be "rung out" to verify proper markings and location.

3. All MXLV/MXLRV hardware connections must first be disconnected to properly test the field wiring, junction points and terminal strip connections.

4. Prior to actual value testing, a final ring out shall be performed to assure that the proper circuits are wired and located as designed.

5. The following connections and straps must be in place prior to testing:

   a. The wiring between the TSC-M and the IC, must be temporary roughed thru the TSC-M (unterminated) and terminated at the MXLRV. After the final testing performed by Pyrotronics, the temporary IC wiring between the TSC-M and MXLRV must be pulled out into the TSC-M and terminated at the TSC-M.

   b. All end of line (EOL) devices must not be installed in any of the TSC's.

   c. All TSC-I wiring except ALD wiring, must be strapped thru using the same type of field wiring.

C. EXECUTION

1. General

   a. Wiring shall be checked and pre-tested by the Contractor, in accordance with this procedure and the manufacturer's recommendations, to ensure that the system is free of shorts, opens and ground faults.

   b. A copy of all pre-test reports (see attached TSC-M pre-test report), shall be submitted to the Engineer for approval, prior to performance testing.

2. Test performance

a. Visual inspection - Inspect cables for physical damage and proper connection in accordance with the reference drawings.

b. Insulation resistance - Test all wires and cables installed under this contract (and as outlined below), with a 1000-Volt Megohmmeter (megger). Applied potential to be 1000 Volts DC for 1 minute. Minimum insulation resistance values shall be not less than 2 Megohms.

Red Conductor to Black Conductor: _____ MΩ.

Red Conductor to shield: _____ MΩ.

Black Conductor to shield: _____ MΩ.

Red Conductor to ground: _____ MΩ.

Black Conductor to ground: _____ MΩ.

Shield to ground: _____ MΩ.

c. Stray Voltage - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

Red Conductor to Black Conductor: _____ AC Volts.

Red Conductor to Black Conductor: _____ DC Volts.

d. Analog device circuits (ALD) - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor: _____ μF.
Maximum value shall be 0.1 μF.

Red Conductor to shield: _____ μF.
Maximum value shall be 0.2 μF.

Black Conductor to shield: _____ μF.
Maximum value shall be 0.2 μF.

2. Resistance
Total of both conductors: _____ Ω.
Maximum value shall be 1.25Ω.

e. Telephone zone circuits (ZCT) - Test all wires and cables installed under this contract (and as outlined below), with

the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor: _____ μF.
Maximum value shall be 0.012 μF.

Red Conductor to shield: _____ μF.
Maximum value shall be 0.025 μF.

Black Conductor to shield: _____ μF.
Maximum value shall be 0.025 μF.

2. Resistance

Total of both conductors: _____ Ω.
Maximum value shall be 1.25Ω.

f. Strobe circuits (ZC1-8B-25) - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor: _____ μF.
Maximum value shall be 0.012 μF.

Red Conductor to shield: _____ μF.
Maximum value shall be 0.025 μF.

Black Conductor to shield: _____ μF.
Maximum value shall be 0.025 μF.

2. Resistance
Total of both conductors: _____ Ω.
Maximum value shall be 1.25Ω.

g. Speaker circuits (ZC2-8b-25) - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

Red Conductor to Black Conductor: _____ μF.
Maximum value shall be 0.012 μF.

Red Conductor to shield: _____ μF.
Maximum value shall be 0.025 μF.

Black Conductor to shield: _____ μF.

Maximum value shall be 0.025 μF.

2. Resistance
   Total of both conductors: _____ Ω.
   Maximum value shall be 1.25Ω.

h. IC/ALD circuits - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

   Red Conductor to Black Conductor: _____ μF.
   Maximum value shall be 0.1 μF.

   Red Conductor to shield: _____ μF.
   Maximum value shall be 0.2 μF.

   Black Conductor to shield: _____ μF.
   Maximum value shall be 0.2 μF.

2. Resistance
   Total of both conductors: _____ Ω.
   Maximum value shall be 5.00Ω.

i. Spare circuits - Test all wires and cables installed under this contract (and as outlined below), with the Fluke 87 Multimeter:

1. Capacitance

   Red Conductor to Black Conductor: _____ μF.
   Maximum value shall be 0.012 μF.

   Red Conductor to shield: _____ μF.
   Maximum value shall be 0.025 μF.

   Black Conductor to shield: _____ μF.
   Maximum value shall be 0.025 μF.

2. Resistance
   Total of both conductors: _____ Ω.
   Maximum value shall be 1.25Ω.

j. A copy of all test results reports (see attached TSC-M test results report), shall be submitted to the Engineer for approval.

3.03 MXLRV/AMPLIFIER CABINETS WIRING

A. General

1. MXLRV/Amplifier Cabinets Composition

a. 120 Volt AC power supply

b. TSC & NTC final connections

c. Low level audio inter-connections

d. High level audio inter-connections

e. System control circuits

f. 24 Volt DC battery power

g. Grounding

B. Test Preparations

1. All field wiring prior to testing, must be fully completed, including terminal strip connections, heat shrink insulating tubing, drain/shield connections, etc.

2. All circuits must be "rung out" to verify proper markings and location.

3. The 120 volt, power wiring connections from the Fuse Cut-Off, must first be disconnected to properly test the field wiring.

4. Prior to actual value testing, a final ring out shall be performed to assure that the proper circuits are wired and located as designed.

B. EXECUTION

1. General

a. Wiring shall be checked and pre-tested by the Contractor, in accordance with this procedure and the manufacturer`s recommendations, to ensure that the system is free of shorts, opens and ground faults.

b. A copy of all pre-test reports (see attached MXLRV/Amplifier Cabinets pre-test report), shall be submitted to the Engineer for approval, prior to performance testing.

2. Test performance

a. Visual inspection - Inspect cables for physical damage and proper connection in accordance with the reference drawings.

b. Insulation resistance - Perform insulation resistance test on each of the 120 volts, power feed conductors with respect to ground and adjacent conductor with a 1000-Volt Megohmmeter (megger). Applied potential to be 1000 Volts DC for 1 minute. Minimum insulation resistance values shall be not less than 2 Megohms.

White Conductor to Black Conductor: _____ MΩ.

White Conductor to ground: _____ MΩ.

Black Conductor to ground: _____ MΩ.

c. System voltage - Test the 120 volt power feed wires, at the Amplifier cabinet PS-35 power inputs, terminals 1 & 2, as outlined below, with the Fluke 87 Multimeter:

White Conductor to Black Conductor: _____ Volts.

d. A copy of all test results reports (see attached MXLRV/Amplifier Cabinets test results report), shall be submitted to the Engineer for approval.

e. Refer to the Port Authority specifications in item 1.02 - REFERENCES, for additional test requirements.

END OF SECTION

SECTION 16110

RACEWAYS

PART 1 - GENERAL

1.01 SUMMARY

This Section specifies requirements for raceways.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American National Standards Institute (ANSI)

ANSI C 80.1 Rigid Steel Conduit - Zinc Coated

ANSI C 80.3 Electrical Metallic Tubing - Zinc Coated

ANSI C 80.5 Rigid Aluminum Conduit

National Electrical Manufacturers Association (NEMA)

NEMA FB 1 Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies

National Fire Protection Association (NFPA)

NFPA 70 National Electric Code

Underwriters Laboratories Inc. (UL)

UL 1 Flexible Metal Conduit

UL 5 Surface Metal Raceways and Fittings

UL 6 Rigid Metal Conduit

UL 360 Electrical Liquid-tight Flexible Steel Conduit

UL 514B Fittings for Conduit and Outlet Boxes

UL 797 Electrical Metallic Tubing

UL 870 Wireways, Auxiliary Gutters, and Associated Fittings

UL 884 Underfloor Raceways and Fittings

UL 1242 Intermediate Metal Conduit

(page 1 omitted)

1.03 QUALITY ASSURANCE

Raceways, of types and sizes required, shall have been satisfactorily used for purposes similar to those intended herein for not less than three years.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver material in manufacturer's original, unopened, protective packaging. Protective caps shall be removed immediately prior to installation of conduit.

B. Store materials in a clean, dry space and protect them from weather.

C. Handle in a manner to prevent damage to finished surfaces.

1.05 SUBMITTALS

Submit the following in accordance with the requirements of "Shop Drawings, Catalog Cuts, and Samples" of Division 1 - GENERAL PROVISIONS:

A. Shop Drawings

Raceway systems - only when shop drawings are required by the Contract Drawings

B. Catalog Cuts

1. Conduit and Tubing

2. Surface Metal Raceway and Accessories

3. Underfloor Raceway and Accessories

4. Wireways and Auxiliary Gutters

PART 2 - PRODUCTS

2.01 MATERIALS

A. General

1. Locations, types and sizes of raceways are shown on the Contract Drawings.

2. Minimum size of conduit shall be 3/4 inch.

3. Conduit shall be supplied in standard 10-foot lengths in accordance with UL 6.

4. All electrical materials and equipment, for which there are established UL standards, shall bear the UL label.

B. Rigid Metal Conduit

1. GSC - Hot-dipped galvanized steel (thick-wall) conduit shall be threaded and shall conform to UL 6 and ANSI C 80.1.

2. IMC - Intermediate metal conduit, hot-dipped galvanized steel (medium-wall) conduit, shall be threaded and shall conform to UL 1242.

3. ALC - Aluminum conduit shall conform to UL 6 and ANSI C 80.5.

4. All preformed elbows shall be similar in construction to, and of a type designed for use with the appropriate conduit and shall conform to UL 6.

5. All fittings shall be threaded and shall conform to NEMA FB-1.

C. Electrical Metallic Tubing

1. EMT - Electrical metallic tubing (thin-wall) shall be galvanized steel and shall conform to UL 797 and ANSI C 80.3.

2. Unless otherwise shown on the Contract Drawings, all fittings shall be indenter or compression type made of malleable or pressed steel and shall conform to NEMA FB 1.

D. Flexible Metal Conduit

1. FSC - Flexible steel (galvanized) conduit shall conform to UL 1.

2. LSC - Liquid-tight flexible metal conduit shall conform to UL 360.

3. Fittings shall be of a type designed for use with the respective conduit and shall conform to UL 514B.

E. Surface Metal Raceways

1. Surface raceways shall conform to UL 5.

2. Surface metal raceways shall have a complete line of accessories readily available.

F. Underfloor Raceways

1. Duct, fittings, and accessories shall be suitable for encasement in concrete and shall conform to UL 884.

2. Underfloor raceways shall have a complete line of accessories readily available.

G. Wireways and Auxiliary Gutters

1. Wireways and auxiliary gutters shall be seamless galvanized steel construction, hinged cover to be locked with captive screws and shall conform to UL 870.

2. Wireways and auxiliary gutters shall have a complete line of accessories readily available.

H. Fastening Devices

Provide inserts, bolts and washers, or any other type of fastening devices conforming to the requirements of the Section entitled "SUPPORTING DEVICES", required to secure conduits to walls or above hung ceilings. Unless otherwise shown on the Contract Drawings, all fasteners shall be hot-dipped galvanized and of sizes and types recommended by the equipment manufacturer and as approved by the Engineer.

I. Insulated Bushings

Insulated bushings shall be rated 150 degrees C.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Make all bends in accordance with the manufacturer's recommendations and NFPA 70.

2. Ream conduit ends free from burrs prior to installation, and draw joints up tight.

3. Make transitions in conduit from one metal to a dissimilar metal only at boxes or other enclosures, unless otherwise shown on the Contract Drawings.

4. Install concealed conduits or tubing in as direct a line as possible.

5. Install exposed raceways, located above hung or accessible ceilings, parallel with or at right angles to the lines of buildings and as close to the ceiling as possible, unless otherwise shown on the Contract Drawings.

6. Install expansion fittings in all conduits which cross expansion joints or where conduits attach to independent structures.

7. Securely fasten threaded conduits entering enclosures, other than threaded, cast boxes, by means of two lock-nuts, one on each side of the enclosure. Terminate the conduits in insulated bushings.

8. Seal all free ends of empty conduit to prevent water entrance.

9. For conduit through roofs and external walls of buildings, manholes and other construction, seal openings watertight in a manner approved by the Engineer.

10. Where portions of an interior raceway system are exposed to widely different temperatures, make provisions to prevent circulation of air from a warmer to a colder section through the raceways.

11. Apply red lead paint to all exposed threads after joints have been made up clean and tight.

12. Support all conduits in a manner approved by the Engineer. Supports shall be spaced to prevent sagging of the conduits.

13. All conduit runs shall leave or enter structures perpendicularly.

B. Rigid Metal Conduit

1. Install only rigid metal conduit type GSC in areas classified as hazardous, for fire alarm systems and where shown on the Contract Drawings.

2. Rigid metal conduits to be installed underground shall be concrete encased, unless otherwise shown on the Contract Drawings. Details for encasement are shown on the Contract Drawings. Concrete encasement shall be in accordance with the Section entitled "CONCRETE."

3. IMC may be used in locations other than those prohibited by codes, which would be applicable, if the Authority were a private corporation and where type GSC is not required by 3.01 B.1 above.

C. Electrical Metallic Tubing

EMT used for power feeder or branch circuits, shall not exceed 2-inch trade size. EMT used for control circuits and communications systems shall not exceed 4-inch trade size.

D. Flexible Metal Conduit

1. Install FSC for motor connections and for other equipment connections where subject to movement and vibration. Conduit shall be installed to permit maximum flexibility,

without crushing or permanent deformation, and shall not exceed 18 inches in length, without approval of the Engineer.

2. Use LSC for the same installation conditions as FSC above, and where also subjected to one or more of the following conditions:

   a. Exterior locations;

   b. Condensating, moist, wet or humid conditions;

   c. Corrosive atmospheres;

   d. Water spray;

   e. Dripping oil, grease or water.

3. Install FSC and LSC with a separate, insulated copper, code-sized equipment grounding conductor, installed either inside or outside the flexible conduit.

E. Surface Metal Raceways

1. Only metallic surface metal raceways will be permitted, unless otherwise shown on the Contract Drawings. Installation shall be in accordance with manufacturer's written recommendations and instructions accompanying the raceways.

2. Provide surface raceway system with means for assuring a continuous ground path throughout.

3. Use fittings without sharp edges introduced into any part of the raceway system.

F. Underfloor Raceways

1. Install underfloor raceways in accordance with NFPA 70 and the recommendations and requirements of the manufacturer and the listing agencies, including, but not limited to UL, Factory Mutual (FM) or Electrical Testing Laboratories (ETL).

2. Power and communications outlets shall be the types and model numbers as shown on the Contract Drawings.

3. Provide power and communications outlets with "Palucell" packets, as shown on the Contract Drawings. No substitutions will be permitted.

G. Dissimilar Metals

1. "Dissimilar metals" shall mean those metals which are incompatible with one another in the presence of moisture, as determined from their relative positions in the Electrochemical Series, or from test data.

2. Where dissimilar metals come in contact, paint the joint both inside and out with approved coating to exclude moisture from the joint, or provide a suitable insulating barrier separating the metals.

3.02 FIELD TESTS

A. Conduit Cleaning and Testing

1. After installation of conduits and accessories and completion of all concreting operations, if any, carefully clean and clear all conduit runs of all obstructions and foreign matter to the satisfaction of the Engineer.

2. Test conduits, in the presence of the Engineer, by pulling through each conduit a flexible cylindrical mandrel having an outside diameter not more than 1/4 inch smaller than the inside diameter of the conduit, but nominally 85 percent of the trade diameter, whichever is larger. Only nylon cable of adequate strength shall be used to pull the mandrel through the conduit system. The use of rope will not be permitted.

B. Connections to Existing Conduits

1. Where conduits installed under this Contract are connected to existing conduits, or conduits installed by others, test the entire run to the nearest box, manhole, handhole, or equipment enclosure as specified in 3.02 A.2 above.

2. Report immediately to the Engineer any defect or stoppage found in portions of the conduit system not installed under this Contract. Do not attempt to rectify any defect or stoppage found in conduit not installed under this Contract unless specifically instructed to do so by the Engineer. The Contractor's compensation for the rectifying of such defects or stoppages at the direction of the Engineer will be determined in accordance with the clause of the Contract providing compensation for Extra Work.

3. The Engineer shall be the sole judge as to whether a defect or stoppage exists. Perform all tests required by the Engineer to enable him to make his decision.

END OF SECTION

DIVISION 16

SECTION 16120

WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)

PART 1 - GENERAL

1.01 SUMMARY

This Section specifies requirements for wires, cables, splices, terminations, and appurtenances for electrical systems of 600 volts or less.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American Society for Testing and Materials (ASTM)

ASTM B 1	Hard-Drawn Copper Wire
ASTM B 2	Medium-Hard-Drawn Copper Wire
ASTM B 3	Soft or Annealed Copper Wire
ASTM B 8	Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B 33	Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM B 174	Bunch-Stranded Copper Conductors for Electrical Conductors
ASTM B 189	Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes
ASTM D 1373	Medium-Voltage Rubber Insulating Tape
ASTM D 2802	Ozone-Resistant Ethylene-Propylene-Rubber Insulation for Wire and Cable
ASTM D 3005	Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape

Federal Specifications (FS)

HH-I-553	Insulation Tape, Electrical (Rubber, Natural and Synthetic)

Insulated Cable Engineers Association (ICEA)

ICEA S-19-81	Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (NEMA WC 3)
ICEA S-61-402	Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (NEMA WC 5)
ICEA S-66-524	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (NEMA WC 7)
ICEA S-68-516	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (NEMA WC 8)

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 383	Type Test of Class 1E Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations
IEEE 837	Standard for Qualifying Permanent Connections Used in Substation Grounding

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code
NFPA 258	Standard Research Method for Determining Smoke Generation of Solid Materials

Underwriters Laboratories Inc. (UL)

UL 44	Rubber-Insulated Wires and Cables
UL 62	Flexible Cord and Fixture Wire
UL 83	Thermoplastic-Insulated Wires and Cables
UL 467	Grounding and Bonding Equipment
UL 510	Insulating Tape
UL 854	Service-Entrance Cables
UL 1581	Reference Standard for Electrical Wires, Cables, and Flexible Cords

1.03 QUALITY ASSURANCE

A. Wires and cables which have been manufactured more than two years prior to installation shall not be used in the Work of this Section.

B. Tapes for splices or terminations shall be dated by the tape manufacturer to indicate that they have been manufactured no longer than six months prior to use in the Work of this Section.

C. Polyvinyl Chloride (PVC): PVC-insulated power wiring and items containing PVC, except PVC-insulated wiring for communications systems, remote control, signaling, and power-limited circuits, shall not be installed in any indoor area. PVC-insulated wiring for communications systems, remote control, signaling, and power-limited circuits shall be furnished and installed in accordance with NFPA 70.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Single conductor wire or cable sizes #4/0 AWG and larger that are to be installed in the same raceway shall be paralleled by the cable manufacturer prior to shipment. Cable assembly overall diameter shall be kept to a minimum.

B. Wire and cable sizes #4/0 AWG and larger shall be provided with factory-applied caps unless otherwise shown on the Contract Drawings. End seals shall be heat-shrink, irradiated, modified polyolefin, and shall be sized for individual wires and cables.

C. Store material in a clean, dry space and protect from weather.

1.05 SUBMITTALS

A. Submit Catalog Cuts for the following in accordance with the requirements of "Shop Drawings, Catalog Cuts, and Samples" of Division 1 - GENERAL PROVISIONS:

1. Wires and cables for each type and size;

2. Splice kit materials and installation procedures.

B. Submit certified shop test reports for wires and cables.

C. Submit field test results for wires and cables, including "Megger" readings with the method used.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

Subject to compliance with requirements of this Section, provide wires, cables, wire and cable splicing, terminating and arcproofing materials of one of the following manufacturers, or approved equal:

A. Wires and Cables

1. American Insulated Wire Corporation
2. Pirelli Cable Corporation
3. Okonite Company
4. BIW Cable Systems, Inc.
5. Rome Cable Corporation
6. Triangle PWC, Inc.
7. Cablec Insulated Cable Company
8. Brand Rex Company

B. Cable Splicing, Terminating and Arcproofing Materials

1. Square D Company
2. Thomas and Betts Corporation
3. Burndy Corporation
4. Cadweld (Erico Products Inc.)
5. Raychem Corporation
6. *Minnesota Mining and Manufacturing Company* (3M)
7. MAC Products Inc.
8. Bishop Electric Corporation
9. Plymouth Rubber Company, Inc.
10. Okonite Company

2.02 WIRES AND CABLES

A. General

1. Locations, types, sizes and numbers of wires and cables are shown on the Contract Drawings.

2. Unless otherwise shown on the Contract Drawings, solid conductors shall be soft or annealed copper, conforming to ASTM B 33 (tinned), ASTM B 189 (lead-coated or lead-alloy coated), or ASTM B 3 (uncoated). Unless otherwise specified in this Section or unless otherwise shown on the Contract Drawings, stranded copper conductors shall be concentric stranding conforming to ASTM B 8.

3. Color-Coding for Power and Lighting Conductors

   a. Insulation or covering of wires and cables shall be factory color-coded by the use of colored compounds or coatings. The color-code shall be followed consistently throughout the performance of the Work.

   b. Upon written request of the Contractor, the Engineer may permit the use of the following methods in lieu of the wire or cable manufacturer's color-coding, when limited quantities of wire and cable are involved, for sizes #8 AWG and larger.

      (1) For dry locations only, spiral application of 3/4 inch wide, colored pressure sensitive plastic tape, half lapped for a distance of not less than six inches may be used. To prevent unwinding, the last two wraps of tape shall be applied with no tension.

      (2) For wet or dry locations, application of three, 3/16 inch wide, colored, fungus-inert, self-extinguishing, self-locking, nylon cable ties spaced 3 inches apart may be used. The ties shall be snugly applied with a special tool or pliers, and any excess removed.

      (3) Each wire and cable shall be color-coded at all terminal points, in all manholes, boxes, or other similar enclosures.

      (4) Color markings shall be applied so as not to obliterate the manufacturer's identification markings.

   c. Color code chart shall be as follows:

	System Voltage	
Conductor	208Y/120V	480Y/277V
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Gray
Ground	Green	Green

4. All wires, cables, splices and terminations, for which there are established UL standards, shall bear the UL label.

B. General-Purpose Wires and Cables

1. General-purpose wires and cables shall be single conductor, ASTM B 8, Class B stranded for sizes #8 AWG and larger, and solid for sizes #10 AWG and smaller.

2. Unless otherwise shown on the Contract Drawings, general-purpose wires and cables for interior use shall be low smoke, low toxicity, non-halogen, flame-retarding type. Cablec "RHH-VW-1 Non-Halogen", Pirelli "Pirelliflex-Afumex Type TC (XHHW-VW-1)", BIW "Lo-Smoke", or approved equal.

3. Where shown on the Contract Drawings, wires or cables shall be:

   a. Type XHHW: Cross-linked-thermosetting-polyethylene insulation, conforming to UL 44, interior use.

   b. Type FEP: Fluorinated-ethylene-propylene insulation, conforming to UL 83, interior use.

   c. Type USE: Ethylene-propylene-rubber insulation, with heavy-duty thermosetting chloro-sulphonated polyethylene or heavy-duty neoprene jacketed, multiple rated "USE-RHH-RHW", conforming to ASTM D 2802, ICEA S-68-516, UL 44 and UL 854, interior or exterior use.

4. Unless otherwise shown on the Contract Drawings, cross-linked-thermosetting-polyethylene insulation shall not be provided for installations which may be subject to moisture or where installed below grade.

5. Type SF-2 shall be provided where high temperature wire or cable is shown on the Contract Drawings.

C. Aerial Cables

Two or more Type SE, ASTM B 8, Class B or Class C stranded, hard-drawn copper conductors, ethylene-propylene-rubber insulation, with heavy duty neoprene or heavy duty thermosetting chloro-sulphonated polyethylene jacketed, marked "sunlight resistant", conforming to ASTM D 2802, UL 44 and UL 854. Cable shall be factory assembled with copper-clad messenger conforming to ICEA S-68-516.

D. Portable Cords

1. Type S shall be 60 degrees C rated, with heavy-duty thermosetting insulation and jacket, conforming to UL 62, 600-volt rated.

2. Type SO shall be oil resistant, 60 degrees C rated, with heavy-duty thermosetting insulation and jacket, conforming to UL 62, 600-volt rated.

3. Type G or Type W shall be 90 degrees C rated, with ethylene-propylene-rubber insulation and Hypalon jacket, 600-volt rated.

4. Special types shall be used only where shown on the Contract Drawings.

E. Lighting Fixture Wires

Unless otherwise shown on the Contract Drawings, lighting fixture wires shall be stranded only, and shall be Type SF-2, silicone rubber insulated conforming to UL 62.

F. Grounding Wires and Cables

Unless otherwise shown on the Contract Drawings, grounding conductors shall be as follows:

1. Insulated

a. Solid for sizes #8 AWG and smaller; ASTM B 8, Class B stranded for sizes #6 AWG and larger; and of the same insulation type as the power conductors.

b. Covering shall be a continuous green color and conform to ASTM B 33 and UL 44.

2. Uninsulated

a. General

Solid for sizes #8 AWG and smaller; ASTM B 8, Class B stranded for sizes #6 AWG and larger.

b. In raceways

Soft-drawn and conforming to ASTM B 3.

c. Direct buried or encased in concrete

Soft-drawn, medium-hard-drawn, or hard-drawn and conforming to ASTM B 1, B 2 or B 3, respectively.

G. Control Wires and Cables

1. Single conductor wires and cables shall be ASTM B 8, Class B stranded, 600-volt, sizes as shown on the Contract Drawings, Type XHHW cross-linked-thermosetting-polyethylene insulation, conforming to UL 44 and ICEA S-66-524.

2. Multiconductor cables shall be ASTM B 8, Class B or Class C stranded, Control Cable Type B, conforming to ICEA S-61-402, color-coded as per ICEA S-61-402, Method No. 1 for NFPA 70 applications (with white and green) or ICEA S-19-81, for color-coding paired conductor cables.

   a. Wires and cables for interior use shall be either of the following types:

      (1) Flame-retardant, low smoke density rating, ethylene-propylene-rubber insulation with overall heavy-duty thermosetting jackets conforming to ICEA S-68-516, UL 44, and UL 1581. The jacket shall not exceed a smoke density rating DM (specific optical density) of 232 and 292 maximum in the flaming and non-flaming modes, respectively, of NFPA 258.

      (2) Ethylene-propylene-rubber insulation with individual and overall heavy-duty thermosetting jackets, conforming to ICEA S-68-516 and vertical tray flame test of IEEE 383.

   b. Wires and cables for exterior use shall be either of the following types:

      (1) Polyethylene insulation with individual and overall polyvinyl chloride jackets, conforming to ICEA S-61-402.

      (2) Cross-linked-thermosetting-polyethylene insulation with overall polyvinyl chloride jackets, conforming to ICEA S-66-524 and vertical tray flame test of IEEE 383.

H. Switchboard Wires and Cables

1. Switchboard wires and cables shall be single conductor, ASTM B 8, Class B stranded, except that for wires and cables crossing hinged joints and swinging panels, and where "Extra Flexible" wire or cable is shown on the Contract Drawings, conductors shall be ASTM B 174, Class K stranded.

2. Wires and cables shall be Type SIS, cross-linked-thermosetting-polyethylene insulation, conforming to ICEA S-61-402, IEEE 383 and UL 44.

I. Cable Tags

1. Dry Locations

a. Fiberglass tags, 1/16 inch thick and 3/4 inch wide, indented with letters and numbers 5/16 inch high, with #14 AWG copper or nylon, weather-resistant cable ties.

b. Lighting branch circuit wiring and single conductor signal and control wiring may be identified with "Quiklables" manufactured by W. H. Brady Company, or approved equal.

2. Wet Locations

Stainless steel metal tags, No. 28 gauge and 3/4 inch wide, embossed with letters and numbers 5/16 inch high, with #14 AWG copper or nylon, weather-resistant cable ties, or stainless steel cable ties.

2.03 SPLICING, TERMINATING AND ARCPROOFING MATERIALS

A. General

1. All splicing, terminating and arcproofing materials shall be compatible so that no one material will adversely affect the physical or electrical properties of any other, or of the wire or cable itself.

2. All materials for making splices and terminations shall be specifically designed for use with the type of wire or cable, insulation and installation and operating conditions of the specific application.

B. Connectors

Subject to compliance with requirements of this Section, provide connectors of the following types:

1. Solderless, uninsulated, high conductivity, corrosion resistant, compression connectors conforming to UL 467 and IEEE 837;

2. Insulated, indenter type compression butt connectors;

3. Insulated, integral self-locking flexible shell, expandable spring connectors;

4. Uninsulated, indenter type compression pigtail connectors;

5. Welded type connectors.

C. Terminals

Subject to compliance with requirements of this Section, provide terminals of the following types:

1. Solderless, uninsulated, high conductivity, corrosion resistant, compression terminals conforming to UL 467 and IEEE 837;

2. Insulated, compression terminals;

3. Solderless, high conductivity, corrosion resistant, hex screw type, bolted terminals;

4. Welded type terminals.

D. Shrinkable Tubing

Subject to compliance with requirements of this Section, provide shrinkable tubing of the following types:

1. Either irradiated modified polyvinyl chloride or irradiated modified polyolefin heat shrinkable tubing;

2. Cold shrinkable tubing.

E. Tapes and Sealers

1. Vinyl Tapes

Flame-retardant, cold and weather-resistant, 3/4 inch or 1 1/2 inches wide, as required, and conforming to UL 510 and ASTM D 3005.

a. For interior, dry locations, provide 7 mils, conforming to ASTM D 3005 (Type I); Scotch (3M) No. 33, or approved equal.

b. For exterior or damp and wet locations, provide 8.5 mils, conforming to ASTM D 3005 (Type II); Scotch (3M) No. 88, or approved equal.

2. Rubber Tapes

Ethylene-propylene, rubber-based, 30-mil splicing tape, rated for 130 degrees C operation; 3/4 inch and wider (1, 1 1/2, 2 inches) as shown on the Contract Drawings or approved by the Engineer, conforming to ASTM D 1373 and Federal Specification HH-I-553 (Grade A); Scotch (3M) No. 130C, or approved equal.

3. Insulating Putty

Rubber-based, 125-mil elastic filler putty; 1 1/2 inches wide; Scotch (3M) Scotchfil, or approved equal.

4. Silicone Rubber Tapes

Inorganic silicone rubber, 12-mil, 130 degrees C rated, anti-tracking, self-fusing tape; 1 inch wide; Scotch (3M) No. 70, or approved equal.

5. Sealer

Liquid applied, fast-drying sealant; Scotch (3M) Scotchkote, or approved equal.

F. Resin Filled Splices

1. Epoxy Molded Type

Two-piece, snap-together molded bodies, sized for wire or cable, with two-part low viscosity polyurethane insulating and sealing compound, rated for 600 volts, using crimp-type wire connector; Scotch (3M) No. 87-A1, 87-A2 or 87-A3 compound, or approved equal.

2. Re-Enterable Type

Transparent, molded bodies clamped with stainless steel strain-relief bar and shield continuity connectors, sized for wire or cable, with loosely woven polyester spacer web and jelly-like urethane formulation for permanent re-entry capability; Scotch (3M) No. 78-R1 thru 78-R5, with No. 2114 compound, or approved equal.

G. Arcproofing Materials

1. Fire resistant tapes shall be Scotch (3M) No. 77, or approved equal.

2. Glass cloth binding tapes shall be Scotch (3M) No. 69, or approved equal.

H. Special splicing materials and methods shall be as shown on the Contract Drawings.

2.04 SHOP TESTS

A. For quantities as shown on the Contract Drawings, regular dielectric-withstand and insulation-resistance in water tests for wires and cables shall be performed in accordance with UL 44.

B. Flame tests for wires and cables shall be performed in accordance with IEEE 383.

C. The test results shall be certified for each reel/coil/box of wire or cable.

D. Factory inspection and witnessing of tests by the Engineer shall be required for all wires and cables furnished under this Contract. The Engineer reserves the right to require additional testing, or to waive factory inspection or witnessing of tests. The Contractor shall notify the Engineer 14 days in advance of the scheduling of such factory tests.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to pulling wires and cables, clean raceway systems of all foreign matter and perform all operations necessary so as not to cause damage to wires and cables while pulling.

B. Prior to pulling wires and cables into underground conduit systems, place a feeding tube approved by the Engineer at the entrance end of such systems.

3.02 INSTALLATION

A. Wire and Cable Installation

1. General

a. Keep wires and cables dry at all times.

b. Seal wire and cable ends with watertight end seals if splicing or terminating does not follow at once.

c. Before splicing or terminating wires and cables, make a thorough inspection to determine that water has not entered the wires and cables or that the wires and cables have not been damaged.

d. Use adequate lubrication when installing cables in conduits or raceways. Any pulling compounds shall be compatible with the finish of the wires and cables furnished.

2. General Purpose Wires and Cables

a. No wire or cable smaller than #12 AWG shall be used for light and power service.

b. Wires or cables shall be at least #10 AWG for the entire length of branch circuits, where distances to first outlets are as follows:

(1) 100 feet or more on 480Y/277 Volt systems.

(2) 70 feet or more on 208Y/120 Volt systems.

3. Lighting Fixture Wires

a. For wiring within lighting fixtures only, where sizes #14 AWG or smaller are required, use Type SF-2 fixture hookup wire. Type SF-2 wire shall not be used for wiring end-to-end connected fluorescent fixtures.

b. For connecting lighting fixtures to branch circuit conductors, use either Type RHH-VW-1, XHHW or USE, up to 90 degrees C, in dry locations.

4. Grounding Wires and Cables

a. Use bare, uninsulated wire and cable only where shown on the Contract Drawings or where approved by the Engineer.

b. Insulated grounding cable shall be of the type specified in this Section or as shown on the Contract Drawings.

5. Control Wires and Cables

Control wires and cables shall not be smaller than #14 AWG unless otherwise shown on the Contract Drawings.

B. Splicing and Terminating

1. General

Splicing and terminating shall be as specified in this Section. Details of special splicing and terminating shall be as shown on the Contract Drawings. Any splicing or terminating methods other than those specified below, for which the components are in accordance with the requirements of this Section, shall be submitted to the Engineer for approval.

2. General Purpose Wires and Cables

a. Splices in dry locations for sizes #10 AWG and smaller

Splicing shall be completed using one of the following:

(1) Insulated, integral, self-locking flexible shell, expandable spring connectors shall be applied to the twisted conductors. Two, half-lapped layers of vinyl tape, extending to a distance of not less than one inch from the connector, shall be applied.

(2) Compression type, insulated butt connectors shall be applied to the butted conductors by means of an appropriate crimping tool, providing controlled indentation. Two, half-lapped layers of vinyl tape, extending to a distance of not less than one inch from the connector, shall be applied.

(3) Compression type, pigtail connectors shall be applied to the conductors by means of an appropriate crimping tool, providing controlled indentation. The connector shall be covered with a polyamide cap and two, half-lapped layers of vinyl tape, extending to a distance of not less than one inch from the connector, shall be applied.

b. Splices in dry locations for sizes #8 AWG and larger

Splicing shall be completed using all of the following:

(1) Connectors shall be split sleeve solderless type or solderless compression type.

(2) Fill indents of connectors with Scotchfil.

(3) Apply rubber splicing tape equal to the original insulation rating.

(4) Apply two, half-lapped layers of vinyl tape, or a shrinkable tubing.

c. Splices in wet locations

(1) Same as dry locations specified in 3.02 B.2.a and 2.b, except that after vinyl tape is applied, cover with two coats of sealer or shrinkable tubing.

(2) Resin-filled splice shall be covered with two, half-lapped layers of vinyl tape and two coats of sealer or shrinkable tubing.

d. Terminations in dry locations for sizes #10 AWG and smaller

Terminations shall be compression terminals, insulated or uninsulated.

e. Terminations in dry locations for sizes #8 AWG through #3/0 AWG

(1) Ring tongue terminals shall be solderless, uninsulated compression crimp type.

(2) Ring tongue lugs shall be bolted hex screw type.

f. Terminations in dry locations for sizes #4/0 AWG and larger

Ring tongue terminals shall be solderless, uninsulated compression crimp type.

g. Terminations in wet locations

In addition to the dry location terminations specified in 3.02 B.2.d, 2.e and 2.f, cover the entire termination area with two, half-lapped layers of vinyl tape and apply two coats of sealer over the tape.

3. Aerial Cables

Splices and terminations in aerial cables shall be the same as specified in 3.02 B.2.c and 2.g, respectively.

4. Portable Cords

a. Splices shall not be made in portable cords.

b. Terminations shall be made only at apparatus to be served or at branch circuit connection by means of any of the following:

(1) Insulated, integral, self-locking flexible shell, expandable spring, or crimp type connectors;

(2) Insulated, crimp type, compression connectors;

(3) Uninsulated, ring tongue terminals for connection to wire terminal strip block.

5. Lighting Fixture Wires

Connections to branch circuit and to fixture wiring shall be made by either insulated, integral, self-locking flexible shell, expandable spring, or crimp type connectors.

6. Grounding Wires and Cables

a. Splices and terminations shall be installed in accordance with the manufacturer's recommendations.

b. In hazardous or classified locations, splices and terminations shall be solderless high conductivity, corrosion resistant, compression type connectors and terminations shall be clamp type pressure connectors, suitable for such use.

c. All underground connections shall be covered with two coats of asphalt base paint.

7. Control Wires and Cables

   a. Splices shall be made in accordance with the requirements specified in 3.02 B.2.c and shall be enclosed in a re-enterable splicing case. Where shielded cable is shown on the Contract Drawings, the shielding shall be continued through the splice. Shields shall be grounded at one location only unless otherwise shown on the Contract Drawings.

   b. Terminations shall be insulated, indenter type ring tongue terminals.

8. Switchboard Wires

   a. No splices are permitted.

   b. Terminations shall be insulated, indenter type ring tongue terminals.

C. Arcproofing

1. Arcproofing shall be applied where shown on the Contract Drawings.

2. Arcproofing, which has been disturbed for any reason, shall be reinstalled as soon as possible after the disturbance.

3. Arcproofing shall be installed as follows:

   a. Wires and cables shall be grouped by circuit and arcproofing applied over the group of wires and cables comprising one circuit. Splices shall be arcproofed individually and the taping shall join with and be overlapped by the group taping.

   b. Arcproofing shall be applied in two wrappings of half-lapped tape, bound with glass cloth tape applied at the ends of the fire resistant tape, and at intervals not to exceed 24 inches along the entire length of the cables. The two wrappings shall be applied with opposing-lays.

   c. Arcproofing shall be extended into the conduit opening or end bell of the raceway entering a handhole, manhole or box.

   d. Arcproofing tape shall be 1 1/2 inches wide where the diameter of the individual cable, or of the circumscribed circle for the circuit group, is less than 1 3/4 inches. For larger diameters, the tape shall be 3 inches wide.

D. Identification of Wires and Cables

1. Each wire and cable shall be identified by its circuit in all cabinets, boxes, manholes, handholes, wireways and other enclosures and access locations, and at all terminal points.

2. The circuit designations shall be as shown on the Contract Drawings. Tags shall be attached to wires and cables in such a manner as to be readily visible.

3. The tag ties shall be wrapped around all conductors comprising the circuit or feeder to be identified.

4. Wires and cables which are arcproofed shall also be identified outside the applied arcproofing.

3.03 FIELD TESTS

Test all wires and cables installed under this Contract with a 1000-volt Megohmmeter. Furnish the Engineer with a copy of the "Megger" readings together with an outline of the method used. If, in the opinion of the Engineer, any reading is lower than that required by applicable codes, promptly replace the materials involved, at the Contractor's expense, and retest.

END OF SECTION

SECTION 16450

GROUNDING

PART 1 - GENERAL

1.01 SUMMARY

This Section specifies requirements for grounding.

1.02 REFERENCES

The following is a listing of the publications referenced in this Section:

American National Standards Institute (ANSI)

ANSI C 2 National Electrical Safety Code

National Fire Protection Association (NFPA)

NFPA 70 National Electrical Code

NFPA 78 Lightning Protection Code

Underwriters Laboratories Inc. (UL)

UL 96 Lightning Protection Components

UL 96A Installation Requirements for Lightning Protection Systems

UL 467 Grounding and Bonding Equipment

1.03 SUBMITTALS

Submit ground resistance test results.

PART 2 - PRODUCTS

2.01 GENERAL

Furnish grounding elements for switchgear, transformers, cabinets, panelboards, starters and miscellaneous electrical equipment, for all noncurrent-carrying portions of the entire electrical system and for exposed non-electrical systems located in electrical substations or switchgear rooms as required by ANSI C 2, NFPA 70 and building codes which would be applicable, if the Authority were a private corporation.

2.02 GROUND RODS

Ground rods shall be minimum 3/4-inch diameter, copper-clad steel. Unless otherwise shown on the Contract Drawings, ground rods shall be 10-foot long.

2.03 GROUNDING CONDUCTORS

A. Provide grounding conductors in accordance with the requirements of Sections entitled "WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)", "WIRES, CABLES, SPLICES, TERMINATIONS (MEDIUM VOLTAGE)" AND "TAXIWAY AND RUNWAY CABLES", as applicable.

B. Grounding conductors for transformers, substations, switchgear and associated grounding mat or counterpoise installations, shall be copper, minimum #4/0 AWG or as shown on the Contract Drawings.

2.04 ABOVE GRADE CONNECTORS

Connectors to piping, fencing, and conduit systems shall be Burndy Corp. "Type GAR", or approved equal.

2.05 BELOW GRADE CONNECTIONS

Buried cable and ground rod connections shall be exothermic welds, Erico Products Inc. "Cadweld", or approved equal.

2.06 GROUNDING BUSHINGS

Grounding bushing shall be insulated type.

2.07 LIGHTNING PROTECTION COMPONENTS

Lightning protection components shall conform to UL 96.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

Install grounding elements for switchgear, transformers, cabinets, panelboards, starters and miscellaneous electrical equipment, for all noncurrent-carrying portions of the entire electrical system and for exposed non-electrical systems located in electrical substations or switchgear rooms as required by ANSI C 2, NFPA 70 and building codes which would be applicable, if the Authority were a private corporation.

B. Install grounding as shown on the Contract Drawings.

C. Grounding and bonding equipment for use in connection with interior wiring systems shall conform to UL 467.

D. Connect exposed metallic piping or ductwork of any non-electrical system that is located in an electric substation or switchgear room, to ground within the room. Where the run through the electrical room exceeds 15 feet in length, make ground connections at both the entering and leaving points of the piping or ductwork.

E. Ground all noncurrent-carrying metallic enclosures of electrical conductors, or exposed noncurrent-carrying metallic parts of electrial equipment, or of power apparatus.

F. All ground rods in grounding loops shall have less than 5 ohms resistance to ground. All individual or isolated ground rods shall have a maximum of 25 ohms resistance to ground. The maximum overall grounding system resistance to ground shall be as shown on the Contract Dravings.

G. Make all connections of grounding connector cables to ground rods by exothermic welding method.

H. Where the grounding system is a component of a lightning protection system, the installation shall conform to the requirements of NFPA 78, UL 96 and UL 96A.

3.02 FIELD TESTS

Make ground resistance tests at all ground rods to ensure compliance with the requirements specified in 3.01 F above, in the presence of the Engineer, and prepare all test results in tabulated form indicating location and time of each test and soil resistivity measured. If ground resistance on a grounding resistance test is higher than the value specified in 3.01 F, either increase length of rod or add more rods in the grounding system until the required ground resistance is achieved.

END OF SECTION

NTC PRE-TEST REPORT

BUILDING - _____ DATE - _____

NTC PAIR #	MXLRV USAGE	OPEN red to black (MΩ)	OPEN red to shield (MΩ)	OPEN red to ground (MΩ)	OPEN black to shield (MΩ)	OPEN black to ground (MΩ)	OPEN shield to ground (MΩ)	APPLIED SHORT red to black (MΩ)	APPLIED SHORT red to shield (MΩ)	APPLIED SHORT black to shield (MΩ)
1	SPARE									
2	SPARE									
3	SPARE									
4	SPARE									
5	SPARE									
6	SPARE									
7	SPARE									
8	SPARE									
9	Low Level Audio 1 (return)									
10	Low Level Audio 2 (return)									
11	SPARE									
12	RS485 Network "A"									
13	RS485 Network "B"									
14	Low Level Audio 1 (feed)									
15	Low Level Audio 2 (feed)									
16	TEL									

NTC TEST RESULTS REPORT

BUILDING - _____ DATE - _____

NTC PAIR #	MXLRV USAGE	INSULATION red/black (MΩ)	INSULATION red/shield (MΩ)	INSULATION red/ground (MΩ)	INSULATION black/shield (MΩ)	INSULATION black/ground (MΩ)	INSULATION shield/ground (MΩ)
1	SPARE						
2	SPARE						
3	SPARE						
4	SPARE						
5	SPARE						
6	SPARE						
7	SPARE						
8	SPARE						
9	Low Level Audio 1 (return)						
10	Low Level Audio 2 (return)						
11	SPARE						
12	RS485 Network "A"						
13	RS485 Network "B"						
14	Low Level Audio 1 (feed)						
15	Low Level Audio 2 (feed)						
16	TEL						

NTC TEST RESULTS REPORT

BUILDING - _____ DATE - _____

NTC PAIR #	MXLRV USAGE	STRAY VOLTAGE red/black (VAC)	STRAY VOLTAGE red/black (VDC)	CAPACITANCE red/black (μF)	CAPACITANCE red/shield (μF)	CAPACITANCE black/shield (μF)	TOTAL CIRCUIT RESISTANCE (Ω)
1	SPARE						
2	SPARE						
3	SPARE						
4	SPARE						
5	SPARE						
6	SPARE						
7	SPARE						
8	SPARE						
9	Low Level Audio 1 (return)						
10	Low Level Audio 2 (return)						
11	SPARE						
12	RS485 Network "A"						
13	RS485 Network "B"						
14	Low Level Audio 1 (feed)						
15	Low Level Audio 2 (feed)						
16	TEL						

TSC-M PRE-TEST REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

TSC PAIR #	MXLRV USAGE	OPEN red to black (MΩ)	OPEN red to shield (MΩ)	OPEN red to ground (MΩ)	OPEN black to shield (MΩ)	OPEN black to ground (MΩ)	OPEN shield to ground (MΩ)	APPLIED SHORT red to black (MΩ)	APPLIED SHORT red to shield (MΩ)	APPLIED SHORT black to shield (MΩ)
1UP	ALD									
2UP	ALD									
3UP	ALD									
4UP	ALD									
5UP	ALD									
6UP	ALD									
7UP	ALD									
8UP	ALD									
9UP	ALD									
10UP	ALD									
11UP	ALD									
12UP	TEL									
13UP	TEL									
14UP	TEL									
15UP	TEL									
16UP	TEL									
17UP	TEL									
18UP	TEL									
19UP	STROBE									
20UP	STROBE									
21UP	STROBE									
22UP	STROBE									
23UP	STROBE									
24UP	STROBE									
25UP	STROBE									
26UP	STROBE									
27UP	SPKR									
28UP	SPKR									
29UP	SPKR									
30UP	SPKR									
31UP	SPKR									
32UP	SPKR									
33UP	SPKR									
34UP	SPKR									
35UP	SPKR									
36UP	SPKR									
37UP	SPKR									
38UP	SPKR									
39UP	SPKR									
40UP	SPKR									
41UP	SPKR									
42UP	SPKR									

TSC-M PRE-TEST REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

TSC PAIR #	MXLRV USAGE	OPEN red to black (MΩ)	OPEN red to shield (MΩ)	OPEN red to ground (MΩ)	OPEN black to shield (MΩ)	OPEN black to ground (MΩ)	OPEN shield to ground (MΩ)	APPLIED SHORT red to black (MΩ)	APPLIED SHORT red to shield (MΩ)	APPLIED SHORT black to shield (MΩ)
1DN	ALD									
2DN	ALD									
3DN	ALD									
4DN	ALD									
5DN	ALD									
6DN	ALD									
7DN	ALD									
8DN	ALD									
9DN	ALD									
10DN	ALD									
11DN	ALD									
12DN	TEL									
13DN	TEL									
14DN	TEL									
15DN	TEL									
16DN	TEL									
17DN	TEL									
18DN	TEL									
19DN	STROBE									
20DN	STROBE									
21DN	STROBE									
22DN	STROBE									
23DN	STROBE									
24DN	STROBE									
25DN	STROBE									
26DN	STROBE									
27DN	SPKR									
28DN	SPKR									
29DN	SPKR									
30DN	SPKR									
31DN	SPKR									
32DN	SPKR									
33DN	SPKR									
34DN	SPKR									
35DN	SPKR									
36DN	SPKR									
37DN	SPKR									
38DN	SPKR									
39DN	SPKR									
40DN	SPKR									
41DN	SPKR									
42DN	SPKR									

TSC-M TEST RESULTS REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

TSC PAIR #	MXLRV USAGE	STRAY VOLTAGE red/black (VAC)	STRAY VOLTAGE red/black (VDC)	CAPACITANCE red/black (μF)	CAPACITANCE red/shield (μF)	CAPACITANCE black/shield (μF)	TOTAL CIRCUIT RESISTANCE (Ω)
1UP	ALD						
2UP	ALD						
3UP	ALD						
4UP	ALD						
5UP	ALD						
6UP	ALD						
7UP	ALD						
8UP	ALD						
9UP	ALD						
10UP	ALD						
11UP	ALD						
12UP	TEL						
13UP	TEL						
14UP	TEL						
15UP	TEL						
16UP	TEL						
17UP	TEL						
18UP	TEL						
19UP	STROBE						
20UP	STROBE						
21UP	STROBE						
22UP	STROBE						
23UP	STROBE						
24UP	STROBE						
25UP	STROBE						
26UP	STROBE						
27UP	SPKR						
28UP	SPKR						
29UP	SPKR						
30UP	SPKR						
31UP	SPKR						
32UP	SPKR						
33UP	SPKR						
34UP	SPKR						
35UP	SPKR						
36UP	SPKR						
37UP	SPKR						
38UP	SPKR						
39UP	SPKR						
40UP	SPKR						
41UP	SPKR						
42UP	SPKR						

TSC-M TEST RESULTS REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

TSC PAIR #	MXLRV USAGE	STRAY VOLTAGE red/black (VAC)	STRAY VOLTAGE red/black (VDC)	CAPACITANCE red/black (μF)	CAPACITANCE red/shield (μF)	CAPACITANCE black/shield (μF)	TOTAL CIRCUIT RESISTANCE (Ω)
1DN	ALD						
2DN	ALD						
3DN	ALD						
4DN	ALD						
5DN	ALD						
6DN	ALD						
7DN	ALD						
8DN	ALD						
9DN	ALD						
10DN	ALD						
11DN	ALD						
12DN	TEL						
13DN	TEL						
14DN	TEL						
15DN	TEL						
16DN	TEL						
17DN	TEL						
18DN	TEL						
19DN	STROBE						
20DN	STROBE						
21DN	STROBE						
22DN	STROBE						
23DN	STROBE						
24DN	STROBE						
25DN	STROBE						
26DN	STROBE						
27DN	SPKR						
28DN	SPKR						
29DN	SPKR						
30DN	SPKR						
31DN	SPKR						
32DN	SPKR						
33DN	SPKR						
34DN	SPKR						
35DN	SPKR						
36DN	SPKR						
37DN	SPKR						
38DN	SPKR						
39DN	SPKR						
40DN	SPKR						
41DN	SPKR						
42DN	SPKR						

TSC-M TEST RESULTS REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

TSC PAIR #	MXLRV USAGE	INSULATION red/black (MΩ)	INSULATION red/shield (MΩ)	INSULATION red/ground (MΩ)	INSULATION black/shield (MΩ)	INSULATION black/ground (MΩ)	INSULATION shield/ground (MΩ)
1UP	ALD						
2UP	ALD						
3UP	ALD						
4UP	ALD						
5UP	ALD						
6UP	ALD						
7UP	ALD						
8UP	ALD						
9UP	ALD						
10UP	ALD						
11UP	ALD						
12UP	TEL						
13UP	TEL						
14UP	TEL						
15UP	TEL						
16UP	TEL						
17UP	TEL						
18UP	TEL						
19UP	STROBE						
20UP	STROBE						
21UP	STROBE						
22UP	STROBE						
23UP	STROBE						
24UP	STROBE						
25UP	STROBE						
26UP	STROBE						
27UP	SPKR						
28UP	SPKR						
29UP	SPKR						
30UP	SPKR						
31UP	SPKR						
32UP	SPKR						
33UP	SPKR						
34UP	SPKR						
35UP	SPKR						
36UP	SPKR						
37UP	SPKR						
38UP	SPKR						
39UP	SPKR						
40UP	SPKR						
41UP	SPKR						
42UP	SPKR						

TSC-M TEST RESULTS REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

TSC PAIR #	MXLRV USAGE	INSULATION red/black (MΩ)	INSULATION red/shield (MΩ)	INSULATION red/ground (MΩ)	INSULATION black/shield (MΩ)	INSULATION black/ground (MΩ)	INSULATION shield/ground (MΩ)
1DN	ALD						
2DN	ALD						
3DN	ALD						
4DN	ALD						
5DN	ALD						
6DN	ALD						
7DN	ALD						
8DN	ALD						
9DN	ALD						
10DN	ALD						
11DN	ALD						
12DN	TEL						
13DN	TEL						
14DN	TEL						
15DN	TEL						
16DN	TEL						
17DN	TEL						
18DN	TEL						
19DN	STROBE						
20DN	STROBE						
21DN	STROBE						
22DN	STROBE						
23DN	STROBE						
24DN	STROBE						
25DN	STROBE						
26DN	STROBE						
27DN	SPKR						
28DN	SPKR						
29DN	SPKR						
30DN	SPKR						
31DN	SPKR						
32DN	SPKR						
33DN	SPKR						
34DN	SPKR						
35DN	SPKR						
36DN	SPKR						
37DN	SPKR						
38DN	SPKR						
39DN	SPKR						
40DN	SPKR						
41DN	SPKR						
42DN	SPKR						

MXLRV/AMPLIFIER CABINETS PRE-TEST REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

OPEN white/black (MΩ)	
OPEN white/ground (MΩ)	
OPEN black/ground (MΩ)	
APPLIED SHORT white/black (MΩ)	
APPLIED SHORT white/ground (MΩ)	
APPLIED SHORT black/ground (MΩ)	

MXLRV/AMPLIFIER CABINETS TEST RESULTS REPORT

BUILDING - _____ FLOOR - _____ DATE - _____

INSULATION white/black (MΩ)	
INSULATION white/ground (Mohm) (MΩ)	
INSULATION black/ground (Mohm) (MΩ)	
VOLTAGE white/black (VAC)	